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UTILITY PATENT APPLICATION AND FEE TRANSMITTAL (Only for new nonprovisional applications under 37 C.F.R. 1.53(b))		Attorney Docket No. 17900-12	Total Pages: 29
		First Named Inventor or Application Identifier: Sunil Bharitkar and Timothy Shuttleworth	
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APPLICATION ELEMENTS See MPEP chapter 600 concerning utility patent application contents.		ADDRESS TO: Assistant Commissioner for Patents Box Patent Application Washington, D.C. 20231	
<p>1. <input checked="" type="checkbox"/> Fee Transmittal Form (Submit an original, and a duplicate for fee processing.)</p> <p>2. <input checked="" type="checkbox"/> Specification Total Pages 18</p> <ul style="list-style-type: none"> – Descriptive title of the invention – Cross References to Related Applications – Statement Regarding Fed sponsored R & D – Reference to Microfiche Appendix – Background of the Invention – Brief Summary of the Invention – Brief Description of the Drawings (if filed) – Detailed Description – Claim(s) – Abstract of the Disclosure <p>3. <input checked="" type="checkbox"/> Drawing(s) (35 U.S.C. 113) Total Sheets 11</p> <p>4. <input checked="" type="checkbox"/> Declaration, Power of Attorney and Petition Total Pages 2</p> <ul style="list-style-type: none"> a. <input checked="" type="checkbox"/> Not executed (copy) b. <input type="checkbox"/> Copy from a prior application (37 C.F.R. 1.63(d)) (for continuation/divisional with Box 17 completed) (Note Box 5 below) <ul style="list-style-type: none"> i. <input type="checkbox"/> Deletion of Inventor(s) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. 1.63(d)(2) and 1.33(b). <p>5. <input type="checkbox"/> Incorporation By Reference (useable if Box 4b is checked). The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.</p>		<p>6. <input type="checkbox"/> Microfiche Computer Program (Appendix)</p> <p>7. <input type="checkbox"/> Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary) <ul style="list-style-type: none"> a. <input type="checkbox"/> Computer readable copy b. <input type="checkbox"/> Paper copy (identical to computer copy) c. <input type="checkbox"/> Statement verifying identity of above copies </p> <p>8. <input type="checkbox"/> Assignment Papers (cover sheet & documents)</p> <p>9. <input type="checkbox"/> 37 C.F.R. 3.73(b) Statement <input type="checkbox"/> Power of Attorney</p> <p>10. <input type="checkbox"/> English Translation Document (if applicable)</p> <p>11. <input type="checkbox"/> Information Disclosure Statement (IDS)/PTO-1449 <input type="checkbox"/> Copies of IDS Citations</p> <p>12. <input type="checkbox"/> Preliminary Amendment</p> <p>13. <input checked="" type="checkbox"/> Return Receipt Postcard (MPEP 503) (Should be specifically itemized)</p> <p>14. <input type="checkbox"/> Small Entity <input type="checkbox"/> Statement filed in prior appln. Statement(s) Status still proper and desired.</p> <p>15. <input type="checkbox"/> Certified Copy of Priority Document(s) (If foreign priority is claimed)</p> <p>16. <input type="checkbox"/> Other:</p>	

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CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS (37 CFR 1.16(c))	33 - 20	13 X	\$ 18.00	234.00
	INDEPENDENT CLAIMS (37 CFR 1.16(b))	5 - 3	2 X	\$ 78.00	156.00
	MULTIPLE DEPENDENT CLAIMS (if applicable) (37 CFR 1.16(d))			\$260.00	
				BASIC FEE (37 CFR 1.16(a))	\$690.00
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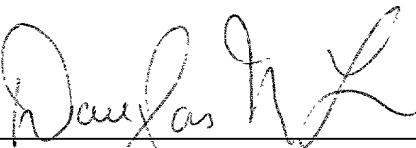
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**SYSTEM AND METHOD FOR VARYING LOW AUDIO FREQUENCIES
INVERSELY WITH AUDIO SIGNAL LEVEL**

I. FIELD OF THE INVENTION

The present invention relates in general to audio speakers and in particular to a method and apparatus based upon the characteristics of the Fletcher-Munson curves for 5 obtaining automatic compensation and equalization of program content as the input signal changes.

II. BACKGROUND OF THE INVENTION

10 The Fletcher-Munson findings are well known in the prior art and generally teach that as the signal level of program material is lowered, the responsiveness of the human ear decreases. The result is that at low volume levels, the human ear is less able to hear bass sounds. Presently, many audio systems utilize a manual loudness control to boost 15 low and high-end response at low volume levels in order to compensate for the decreased responsiveness of the human ear. Such a manual loudness control circuit is illustrated in U.S. Pat. No. 4,490,843.

Other circuits relate to improving the sound quality in automotive systems by 20 implementing a controllable bass contour network coupled to the program source material. However, these circuits utilize notch filters for equalizing the frequency resonance within a vehicle's interior. These circuits also use a feedback circuit to detect 25 and adjust bass levels. Such circuits are shown in U.S. Pat. Nos. 4,809,338 and 4,759,065.

Still other circuits provide automatic loudness compensation to bass boost at 60 Hz. One such circuit utilizes a 2:1 compressor so that the input signals can be 25 compressed such a circuit is shown in U.S. Pat. No. 4,739,514.

It would be advantageous to have a circuit that automatically compensates for the decrease in program material at lower volumes by mimicking the Fletcher Munson curves using the r.m.s. (root mean square) value of an audio signal to boost bass within the 40 – 80 dB range. The circuit would be useful in restaurants, stores or high quality home

stereo systems to boost the bass content of an input audio signal as the strength of the signal decreases.

In one embodiment, a circuit with characteristics of first order bass boost would automatically boost bass by altering the corner frequency of a circuit filter depending on 5 the input signal. A method of providing an automatic loudness compensation circuit comprises receiving an input audio signal containing bass content, coupling the input audio signal to a voltage detector, coupling an output voltage of the voltage detector to a filter circuit, wherein the filter circuit adjusts a corner frequency associated with the filter such that the corner frequency is inversely related to the input audio signal to boost the 10 bass content of the input audio signal, coupling an output of the filter circuit to a power amplifier for amplifying the filter circuit output, and driving an audio speaker with the amplified filter circuit output.

An apparatus according to the invention comprises a terminal for receiving an audio input signal, a power supply voltage having sufficient voltage to drive an audio 15 output speaker, an R.M.S. detector for providing an R.M.S. voltage from the audio input signal, a variable low pass filter circuit for adjusting a corner frequency associated with the low pass filter such that the corner frequency is inversely related to the audio input signal and supplying an output signal which is increased as the audio input signal decreases, a power amplification stage for increasing the power of the output signal from 20 the low pass filter circuit, and a terminal for providing an amplified output signal.

According to another aspect of the invention, there may be a digital signal processor (DSP) filter utilized such that in addition to altering the corner frequency, the 25 DSP filter could also simulate varying the order of the circuit. By controlling the order of the filter circuit, the roll-off associated with the corner frequency could be adjusted to allow for a more accurate simulation of the Fletcher-Munson curves.

III. SUMMARY OF THE INVENTION

The present invention relates to an auto loudness circuit for performing loudness compensation automatically depending on the signal level. When the signal level 5 decreases, loudness compensation is slowly introduced and as the signal level increases, loudness compensation is quickly removed.

In the present invention, an auto loudness circuit utilizes a filter circuit with the characteristic of a first order bass boost. The filter circuit maintains a corner frequency that is proportional to the inverse of audio level in order to mimic the Fletcher-Munson 10 curves. Because the circuit employs a capacitance-multiplier with a first order resistance capacitance filter, the bass boost is inversely proportional to the signal level. Thus, bass boost is achieved automatically as the program content changes so that the listener is unaware of significant changes in program material as signal levels change either through increase or decrease in volume, crescendo or new material.

15 The circuit of the present invention measures the power of the input signal and varies the corner frequency of the filter to be inversely proportional to the input signal. The corner frequency, which is also known as the cut-off frequency, is the highest frequency in the band pass of a filter. However, filters do not immediately cut-off frequencies at the corner frequency due to the limitations of electronic components. 20 Instead, a roll-off results which is the reduction of the signal level as the frequency of the signal moves away from the corner frequency. Signals above the cut-off frequency, which in this application is a very low frequency that is adjusted according to the signal power, decrease in amplitude that results in a decreasing effect.

25 Thus, in one embodiment of the present invention, the corner frequency is proportional to the boost to the signal as it is varied inversely with the signal level. For instance, at high signal levels, where bass is easily heard, the corner frequency of the circuit is set to a very low frequency. This way, with an extremely low value of the corner frequency, no boosting to the bass is applied since none is necessary. But at low 30 signal levels, the corner frequency is shifted to a higher frequency level and begins to result in a boost the bass content of the input audio signal. As the corner frequency increases, the amount of bass boosting continues to increase. In this embodiment the

variable cut-off frequency low pass filter is used in a positive feedback arrangement to boost through gain at low frequencies. Alternatively the same result could be achieved using a high pass filter in a negative feedback arrangement to remove through gain boost at higher frequencies.

5 In another embodiment, a digital signal processing (DSP) circuit may be utilized to adjust the order of the filter to more closely match the Fletcher-Munson curves. In this embodiment, a DSP based on an adaptive number of filter taps (order) is used. The order is determined by the signal level. Moreover, the DSP also controls the corner frequency as discussed above. Thus, as the signal level decreases, the order of the filter increases
10 to allow for sharper roll-off from the corner frequency. The result is a closer simulation of the Fletcher-Munson curves.

In yet another embodiment of the invention, a fuzzy signal processing based system may be utilized. In this embodiment, the input information such as power, rate of increase/decrease of power is encoded, then processed by an expert system, and then
15 decoded to generate outputs such as corner frequency and bass boost.

Thus, it is an object of the present invention to provide a circuit with characteristics of a first order bass boost.

It is another object of the present invention to control the corner frequency of a filter in order to automatically control the loudness compensation of an input audio
20 signal.

It is still another object of the present invention to boost the bass content slowly when the input audio signal decreases and remove the bass boosting quickly when the input audio signal increases such that the bass boost action is not observed by a listener as volume level declines and does not damage audio equipment as volume level increases.

25 Further, it is an object of the present invention to utilize a capacitance-multiplier circuit to vary the bass boost inversely with the audio signal.

Still further, it is an object of the present invention to utilize a variable capacitor circuit to vary the bass boost inversely with the audio signal.

It is still another object of the present invention to utilize a digital signal filter
30 processing circuit in addition to controlling the filter corner frequency to more accurately mimic the Fletcher-Munson curves.

Thus, the present invention relates to a method comprising receiving an input audio signal, coupling the input audio signal to a filter circuit to recover the audio signal, adjusting the corner frequency of the filter circuit as the input audio signal changes, utilizing this filter in a feedback configuration thus boosting the bass slowly when the 5 input audio signal decreases, removing the bass boosting quickly when the input audio signal increases, and driving the audio speaker with the automatic boosting compensation.

The invention also relates to apparatus for obtaining automatic bass boost compensation comprising a terminal for receiving an audio input signal, an R.M.S. (root 10 mean square) detector, a variable corner frequency filter circuit for modifying the corner frequency as audio input signal changes, and a capacitance multiplier controlled by an opto-coupled resistor.

Yet, another embodiment of the automatic bass boost compensation circuit is disclosed which utilizes a DSP filter circuit that is particularly useful for more accurate 15 simulation of the Fletcher-Munson curves.

IV. BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the present invention will be more fully disclosed 20 when taken in conjunction with the following Detailed Description of the Embodiment(s) in which like numerals represent like elements and in which:

FIG. 1 is a frequency domain relative level diagram illustrating the Fletcher-Munson curves;

FIG. 2 is a frequency domain relative level diagram illustrating the Fletcher- 25 Munson curves normalized at 1KHz;

FIG. 3 is a system block diagram of the present invention.

FIG. 4 is a simplified circuit diagram of the auto loudness compensation circuit of the present invention;

FIG. 5A is a circuit diagram of the present circuit utilizing a capacitance 30 multiplier controlled by an opto coupled resistor;

FIG. 5B is a simplified circuit diagram of the present circuit shown with a variable capacitor;

FIG. 6 is a frequency domain relative level diagram simulating the various frequency response curves as a result of the circuit of the present invention;

5 FIG. 7A is an embodiment of a fuzzy logic method for loudness compensation;

FIG. 7B shows a way of encoding the input variable labeled signal power;

FIG. 7C shows a rule base generated by an expert;

FIG. 7D shows a way of decoding the fuzzy variables from the rule base to determine the output variable labeled cutoff frequency; and

10 FIG. 7E shows an exemplary computation performed by the fuzzy system.

V. DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a set of well-known frequency domain relative level curves first 15 developed by Fletcher and Munson in the early 1930's. These frequency domain relative level curves (equal loudness contours) relate to the frequency response of a human ear to the level of signals being heard. As the signal level decreases, research shows that the responsiveness to the signal by the human ear alters, in particular, in relation to this invention, responsiveness to bass frequencies decreases.

20 Referring to FIG. 2, a set of frequency domain relative level curves illustrates the results from the Fletcher-Munson curves after being 'normalized' at 1kHz. Since the Fletcher-Munson curves of FIG. 1 are stable at 1 kHz, the curves were normalized at that frequency. The curves were normalized in order to determine the desired output characteristics for a circuit that performs according to the normalized curves. Thus, the 25 filter circuit of the present invention was designed to perform by closely simulating the Fletcher-Munson curves normalized at 1kHz.

FIG. 3 is a system diagram of the present invention. A compact disc (CD) player 300 or a cassette player 310 may be connected to the system of the present invention as 30 sources of musical content. Switch 330 is controlled by an operator to select the source of the music. Then a level control 340 may be used to remotely determine the level of the audio signal that is then supplied to the circuit. As will be discussed in more detail

below, the circuit 350 determines the volume level of the audio signal in order to determine whether bass boost of the bass content of the audio signal is required. The output of the summer 360 is amplified by amplifier 370 and the output of the amplifier 370 is then sent to the speaker 380 to implement the bass boosting compensation if 5 required.

FIG. 4 is a block diagram of the automatic loudness compensation circuit in one embodiment of the present invention, the positive feedback low frequency boosting arrangement. An input audio signal, V_{in} 400, is received by the circuit and supplied to an r.m.s. detector 410. In this embodiment, the r.m.s. value of the voltage is used because 10 the r.m.s. value closely indicates the perceived volume level or acoustic power. The r.m.s. detector 410 produces an d.c. output voltage, V_{rms} 420, which is a DC voltage proportional to the r.m.s. level of the AC input audio signal. V_{rms} 420 is then supplied to the variable cut-off frequency low pass filter 430. The low passed signal is attenuated by 15 an op amp buffered or passive attenuator 440 and a low passed voltage, V_{lp} is summed with the input audio signal by summing circuit 450. The signal is then amplified by amplifier 460 and provided to the output terminal 470 of the circuit of the present invention.

Referring to FIGS. 5A and 5B, a schematic diagram for the circuit of one aspect of the present invention is shown. In FIG.5A, an AC input signal 500 is received and 20 then supplied to an r.m.s. detector 510. The r.m.s. detector 510 produces a d.c. output voltage, V_{rms} 520, which is then supplied to a light emitting diode (LED) 565. The degree of illumination of the LED 565 controls the resistance of resistor R_0 570, which is part of a capacitance multiplier circuit. The capacitance multiplier circuit 530 includes capacitor 540, operational amplifier 550 and resistors R 575 and R_0 570. In operation, when the 25 V_{rms} 520 is high, LED 565 is energized and the light is on. R_0 570 is an opto-coupled resistor and operates inversely with the LED 565. Thus, when the LED 565 is energized or on, the resistance across R_0 570 decreases quickly and when the LED 565 is de-energized or off, the resistance across R_0 570 increases slowly. Referring now to FIG. 30 5B, the capacitance multiplier circuit 530 is shown as an equivalent variable capacitor, C_e 545, wherein:

$$C_e = \left(\frac{R}{R_0} \right) C \quad 1.1$$

Thus, C_e is inversely proportional to R_0 :

$$C_e \propto \frac{1}{R_0} \quad 1.2$$

5

Further, since capacitance is inversely related to frequency, the corner frequency, f_c is inversely proportional to C_e :

$$f_c \propto \frac{1}{C_e} \quad 1.3$$

10 and then it is seen that

$$f_c \propto R_0 \quad 1.4$$

Finally, since the total bass boost at low frequencies (B) is proportional to the filter passband the amount of bass boosting is proportional to the corner frequency:

15 $B \propto f_c \quad 1.5$

And therefore,

$$B \propto R_0 \quad 1.6$$

Thus, the variable capacitor C_e 545 when fed from the signal output 590 via a resistor functions as a variable low pass filter 555. In order to control the corner frequency, f_c of the low pass filter 555, the value of the resistance across R_0 570 (fig. 5A) is adjusted per equation 1.4. The result of the above interrelationships of the capacitance multiplier circuit components or variable capacitance, C_e 545, is to provide an output signal 590 in which bass boost increases slowly when the input signal 500 is decreasing. Further, the circuit provides an output signal 590 in which bass boost decreases quickly when the input signal 500 is increasing.

25 FIG. 6 shows a frequency domain gain diagram (or frequency response) of the frequency responses which results from the circuit of the present invention. The

waveforms of FIG. 6 closely mimic the Fletcher-Munson waveforms of FIG. 2 normalized about 1kHz.

In yet another embodiment of the present invention, a digital signal processing system modifies the order of the filter in addition to varying the corner frequency of the 5 filter circuit. Thus, the waveforms resulting from this embodiment are more closely modeled to the Fletcher-Munson curves.

In yet another embodiment, the present invention considers an arbitrary function mapping system between the input and output signal variables. For example, a fuzzy 10 system based signal processing scheme may be used to provide a “soft” computing mechanism for the associated system parameters such as signal power, corner frequency, amount of boost, etc. There exist several journals such as IEEE Trans. on Fuzzy Systems, Fuzzy Sets and Systems, etc., and texts such as, “Fuzzy Logic with Engineering 15 Applications,” by Timothy Ross, McGraw-Hill, 1995, etc., that discusses the methodology of fuzzy computing, which is hereby incorporated by reference into this application. Figs. 7(a)-(e) illustrate by way of example one method of using fuzzy logic computing in accordance with the present invention.

In Fig. 7(a), exemplary input parameters (input variables) are provided, such as, signal power 702, rate of increase of signal power 704, rate of decrease of signal power 706. Other input variables such as direction of change in input power may be also used 20 (not shown). These inputs are “fuzzified” by suitable fuzzy sets as shown in Fig. 7(b). These fuzzy sets are also known as membership functions and are expert generated. The fuzzification scheme is an encoding scheme so that the next step in the computing process, an expert generated rulebase, can use this information. As an example, for the input parameter labeled “signal power,” the expert may use the three fuzzy sets, low, 25 medium and high. That is, when the input signal power is 9 W, the encoder provides two nonzero output values. One approximate output is 0.25 for the medium fuzzy set, and the other output is approximately 0.8 for the high fuzzy set. These outputs are fed to a rule base that contains expert generated rules. For example, Fig. 7(c) illustrates by way of example, two rules in the rule base. Only those outputs from the encoder that “activate” 30 the antecedent portion of the rules in the rulebase are typically used to compute the outputs from the rulebase. The outputs are computed from the appropriate consequent of

the rulebase and provided as input to the decoder also known as the defuzzifier. The decoder performs an inverse mapping from the fuzzy variables to crisp variables. Fig. 7(d) illustrates by way of an example the decoder for the output labeled cutoff frequency. In a typical computing environment, an input signal power of 8.43W, and rate of decrease 5 of power (4.46, an arbitrary exemplary scale) is provided to the system, as shown in Fig. 8(e). The computed output values for the signal boost and cutoff frequency are 0.792 and 572 Hz. Several variations of the system can be incorporated (e.g., adaptive encoding and decoding elements, etc.) for finer results.

It will be appreciated that the term “present invention” as used herein should not 10 be construed to mean that only a single invention having a single essential element or group of elements is presented. Rather, each novel and nonobvious element constitutes a separate invention. Further, each novel and nonobvious combination of elements enabled by the present disclosure, whether the individual elements therein be old elements, new elements, or any combination thereof, further constitutes an additional separate invention.

15 Although the present invention has thus been described in detail with regard to the preferred embodiments and drawings thereof, it should be apparent to those skilled in the art that various adaptations and modifications of the present invention may be accomplished without departing from the spirit and the scope of the invention. Accordingly, it is to be understood that the detailed description and the accompanying 20 drawings as set forth hereinabove are not intended to limit the breadth of the present invention, which should be inferred only from the following claims and their appropriately construed legal equivalents. In the following claims, those claims which contain the words “means for” are intended to be interpreted in accordance with 35 U.S.C. § 112, paragraph 6; those claims which do not include the words “means for” are 25 intended to not be interpreted in accordance with 35 U.S.C. § 112, paragraph 6. The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed.

WHAT IS CLAIMED IS:

1. A method of providing an automatic loudness compensation circuit comprising:
 - receiving an input audio signal containing bass content;
 - coupling the input audio signal to a voltage detector having an output voltage;
 - coupling the output voltage of the voltage detector to a filter circuit for adjusting a corner frequency associated with the filter circuit such that the corner frequency is inversely related to the input audio signal for boosting the bass content of the input audio signal; and
 - coupling an output of the filter circuit to a power amplifier for amplifying the filter circuit output.
2. The method of claim 1 wherein the method further comprises driving an audio speaker with the amplified filter circuit output.
3. The method of claim 1 wherein the filter circuit further comprises a capacitance multiplier circuit comprising a light emitting device coupled to a light sensitive resistor.
4. The method of claim 3 wherein the capacitance multiplier circuit further comprises a low pass filter coupled to the light emitting device and the light sensitive resistor.
5. The method of claim 4 wherein the filter circuit adjusts the corner frequency of the low pass filter within an operating frequency range.
6. The method of claim 5 wherein the filter circuit adjusts the corner frequency of the low pass filter such that the corner frequency is increased when the input audio signal decreases.

7. The method of claim 3 wherein the amount boost to the bass content of the input audio signal is proportional to the corner frequency of the low pass filter.

8. The method of claim 3 wherein the amount boost to the bass content of the input audio signal is proportional to the value of the light sensitive resistor.

9. The method of claim 1 wherein the source of the input audio signal is a compact disc.

10. The method of claim 1 wherein the source of the input audio signal is a cassette.

11. The method of claim 1 wherein the source of the input audio signal is a digital video disc.

12. The method of claim 1 wherein the source of the input audio signal is a microphone.

13. The method of claim 12 wherein the output of the filter circuit and the microphone input audio signal are coupled to a summing circuit having an output signal.

14. The method of claim 13 wherein the output of the summing circuit is coupled to the power amplifier.

15. A method of providing an automatic loudness compensation circuit comprising:

receiving an input audio signal including bass content;

coupling the input audio signal to a voltage detector to produce an output voltage;

5 coupling the output voltage of the voltage detector to a control circuit, the control circuit comprising a filter circuit;

comparing a corner frequency associated with the filter circuit to the strength of the input audio signal;

10 shifting the corner frequency such that the corner frequency is inversely related to the strength of the input audio signal;

coupling an output of the filter circuit to a power amplifier for amplifying the filter circuit output; and

driving an audio speaker with the amplified filter circuit output.

16. The method of claim 15, further comprising:

utilizing a capacitance multiplier circuit comprising a light emitting device coupled to a light sensitive resistor having an output signal wherein the output of the light sensitive resistor is coupled to a low pass filter for adjusting the bass content of the input 5 audio signal.

17. The method of claim 16, further comprising:

responding to an increase in the input audio signal by energizing the light emitting device within the filter circuit to produce a light source; and

decreasing the resistance of the light sensitive resistor; and

5 increasing the value of the capacitor in order to shift the corner frequency such that bass boosting of the audio input signal is quickly removed.

18. The method of claim 16 further comprising:

responding to a decrease in the audio input signal by de-energizing the light emitting device within the filter circuit in order to prevent a light source;

increasing the resistance of the light sensitive resistor; and

5 decreasing the value of the capacitor in order to shift the corner frequency such that bass boosting of the audio input signal is slowly added.

19. The method of claim 15 wherein the amount boost to the bass content of the input audio signal is proportional to the corner frequency of the filter circuit.

20. The method of claim 16 wherein the amount boost to the bass content of the input audio signal is proportional to the value of the light sensitive resistor.

21. The method of claim 16, wherein the light sensitive resistor is an opto-coupled resistor.

22. An automatic loudness compensation circuit including a terminal coupled to an input audio signal from an external source and a signal supply having voltage sufficient to drive an output audio speaker comprising:

- an R.M.S. detector for providing an R.M.S. voltage from the input audio signal;
- 5 a control circuit including a filter circuit for adjusting a corner frequency associated with the filter circuit such that the corner frequency is inversely related to the input audio signal;
- a power amplifier for increasing the power of the output signal from the low pass filter circuit; and
- 10 a terminal for providing an amplified output signal.

23. The automatic loudness compensation circuit of claim 22 wherein the control circuit provides a boost to the input audio signal containing a bass content such that the boost is proportional to the corner frequency of the filter circuit.

24. The automatic loudness compensation circuit of claim 22 wherein the filter circuit further comprises a light emitting device coupled to a light sensitive resistor having an output signal wherein the output of the light sensitive resistor is coupled to a low pass filter.

25. The automatic loudness compensation circuit of claim 24 wherein the control circuit provides a boost to the input audio signal containing a bass content such that the boost is proportional to the output of the light sensitive resistor.

26. An automatic loudness compensation circuit including a terminal coupled to an input audio signal from an external source and a signal supply having voltage sufficient to drive an output audio speaker comprising:

means for detecting an R.M.S. voltage from the audio input signal;

5 means for adjusting a corner frequency of a filter circuit such that the corner frequency is inversely related to the audio input signal;

means for amplifying the output signal from the filter circuit; and

a terminal for providing an amplified output signal.

27. A system for obtaining a first order bass boost compensation comprising:

a terminal for receiving an audio input signal having a signal level;

a level control for determining the level of the input audio signal;

an automatic loudness compensation circuit having an output signal comprising:

5 a power supply voltage having voltage sufficient to drive an output audio speaker;

an R.M.S. detector coupled to the power supply voltage for providing an R.M.S. voltage from the input audio signal; and

10 a control circuit coupled to the R.M.S. detector comprising a filter having

an associated corner frequency, the control circuit for adjusting the corner frequency such that the corner frequency is inversely related to the input audio signal;

a summing circuit having an output signal coupled to the automatic loudness compensation circuit for receiving input from a microphone and summing the microphone input to the output of the automatic loudness compensation circuit;

15 a power amplifier coupled to the summing circuit for increasing the power of the output signal from the summing circuit; and

a terminal for providing an amplified output signal to an audio speaker.

28. The method of claim 27, wherein the audio input signal is received from a compact disc player.

29. The method of claim 27, wherein the audio input signal is received from a cassette player.

30. The method of claim 27, wherein the audio input signal is received from a digital video disc player.

31. A system for obtaining an automatic loudness compensation comprising:
a input terminal for receiving an audio input signal having a signal level;
a level control coupled to the input terminal for determining the level of the input audio signal;

5 an automatic loudness compensation circuit having an output signal coupled to the level control comprising a filter circuit for adjusting a corner frequency associated with the filter circuit such that the corner frequency is inversely related to the audio input signal;

10 a summing circuit having an output signal coupled to the automatic loudness compensation circuit for receiving input from a microphone and summing the microphone input to the output of the automatic loudness compensation circuit;

15 a power amplifier coupled to the summing circuit for increasing the power of the output signal from the summing circuit; and

a output terminal coupled to for providing an amplified output signal to an audio speaker.

32. A method for providing an automatic loudness compensation, comprising the steps of:

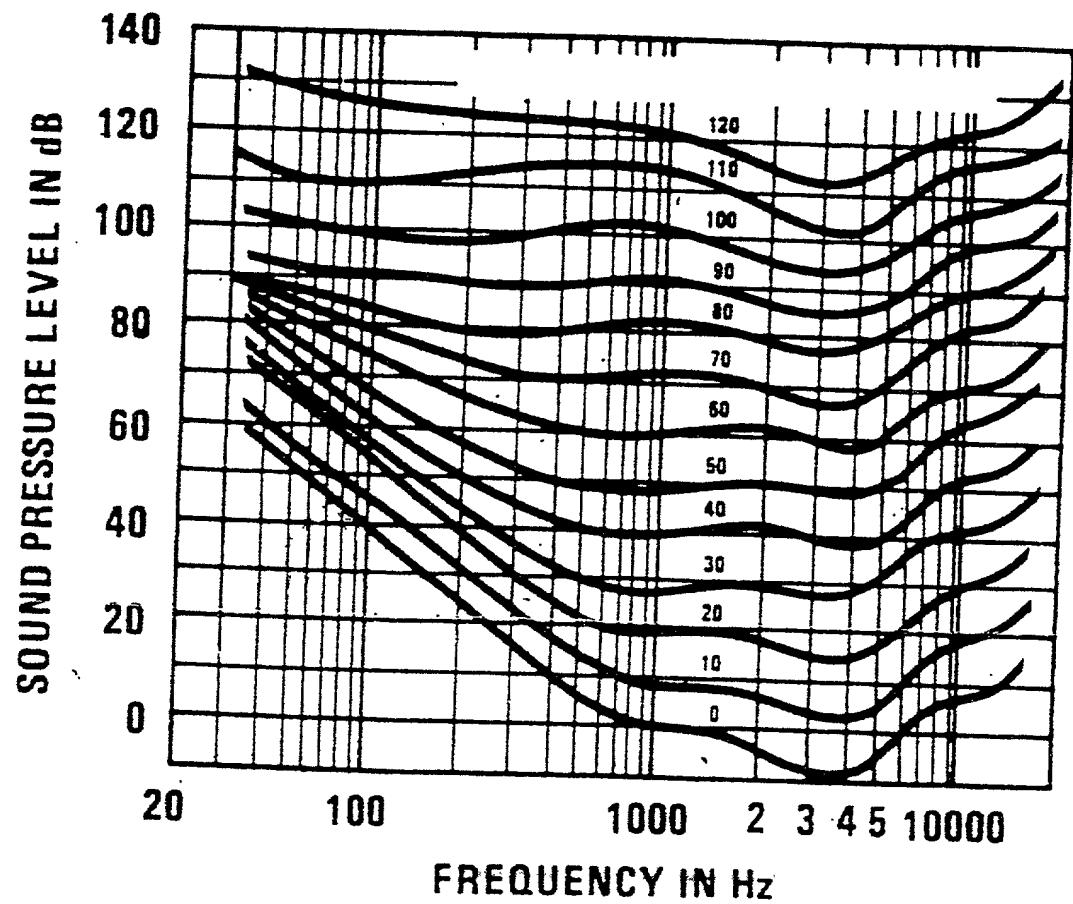
5 encoding input variables
processing said encoded input variables; and,
decoding said processed encoded input variables into output variables.

33. The method of claim 32, wherein the encoding of said input variables is done by fuzzy sets.

34. The method of claim 32, wherein the processing of the encoded input variables is done by an expert.
35. The method of claim 34, wherein the expert is a rulebase.
36. The method of claim 32, wherein the said decoding of the processed encoded input variables is done by defuzzification.

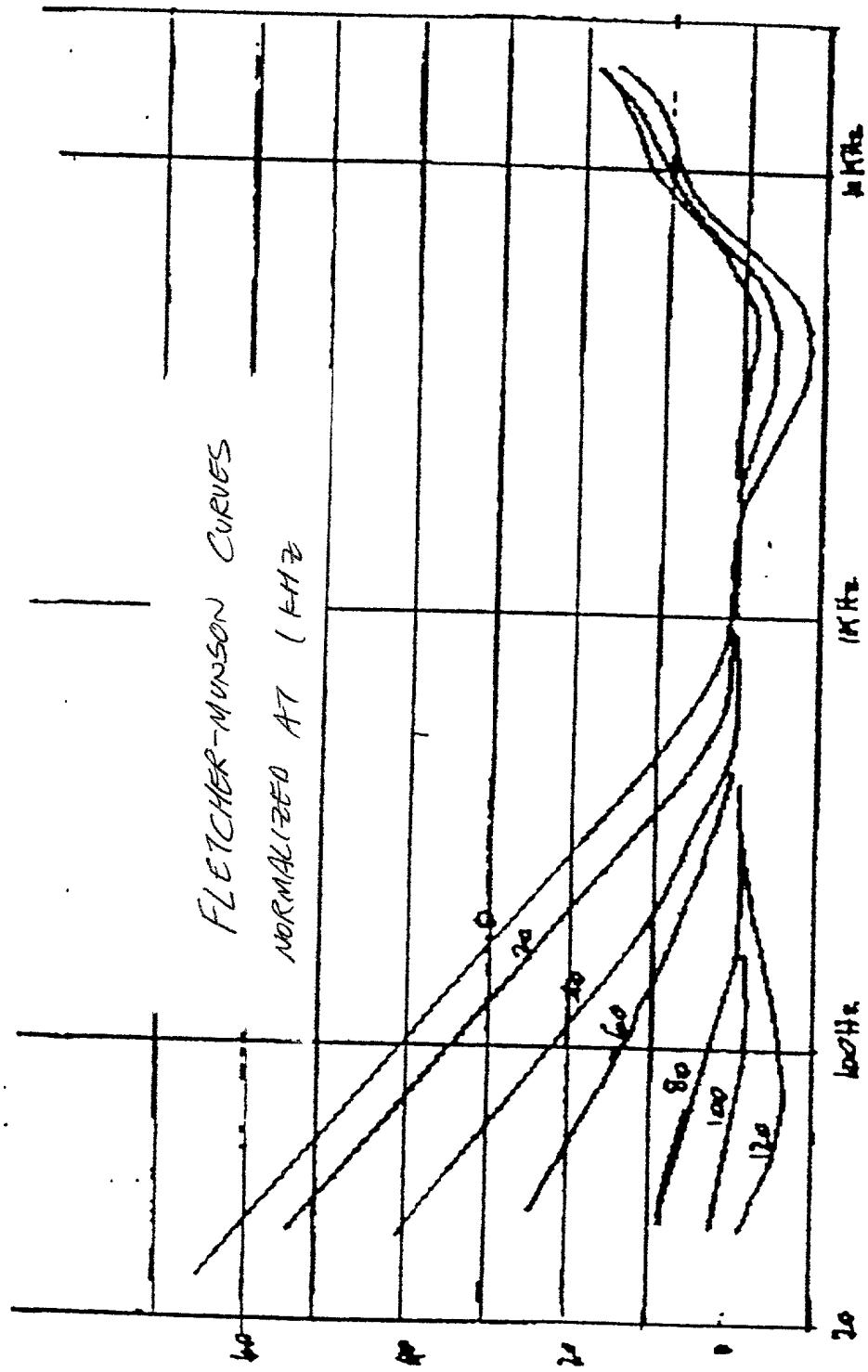
ABSTRACT

The present invention relates to an auto loudness circuit for performing loudness compensation automatically depending on the signal level. When the signal level decreases, loudness compensation is slowly introduced and as the signal level increases, 5 loudness compensation is quickly removed. To do so, the auto loudness circuit utilizes a filter circuit with the characteristic of a first order bass boost. The filter circuit maintains a corner frequency which is proportional to the inverse of audio level in order to mimic the Fletcher-Munson curves. Because the circuit employs a capacitance-multiplier with a first order resistance capacitance filter, the bass boost is inversely proportional to the 10 signal level. Thus, bass boost is achieved automatically as the program content changes so that the listener is unaware of significant changes in program material as signal levels change either through increase or decrease in volume, crescendo or new material.



Fletcher-Munson Curves

FIG. 1



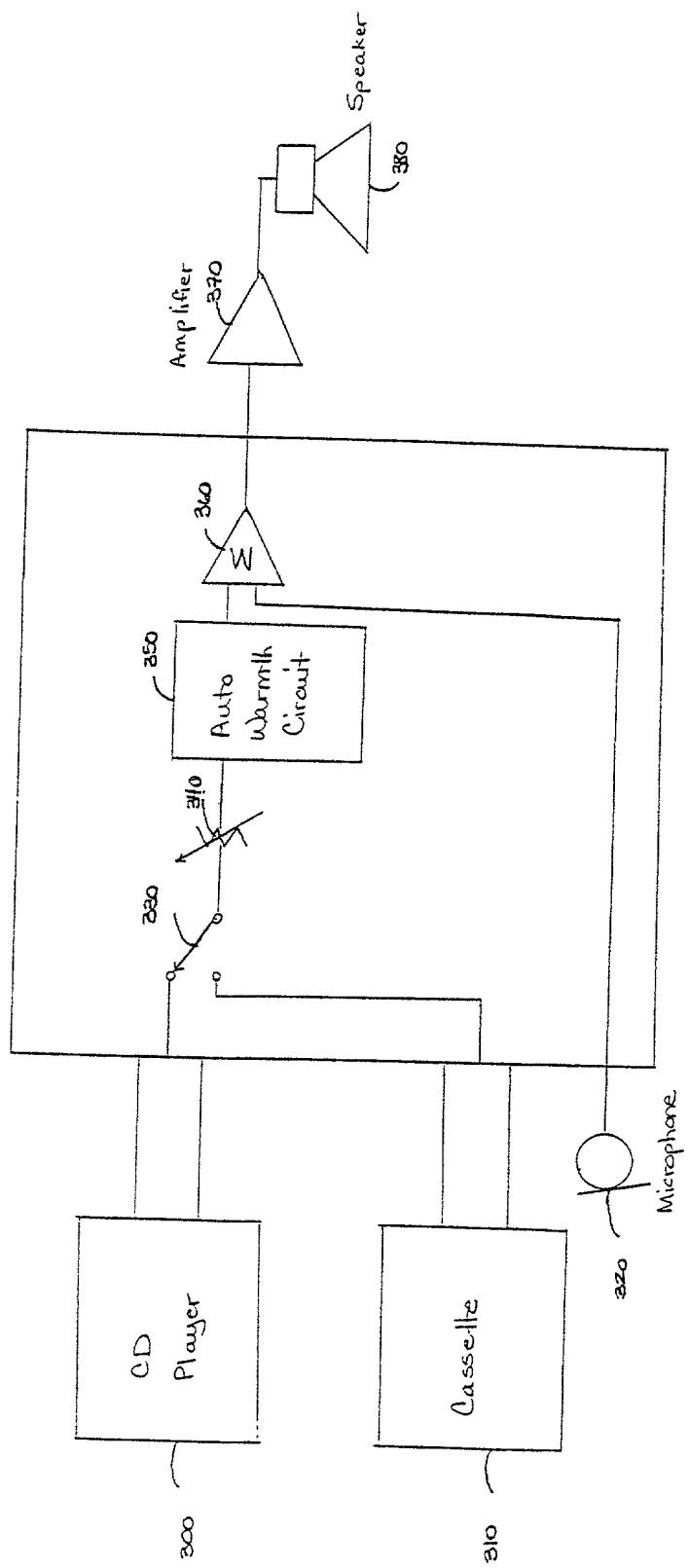


FIG. 3

FIG. 4

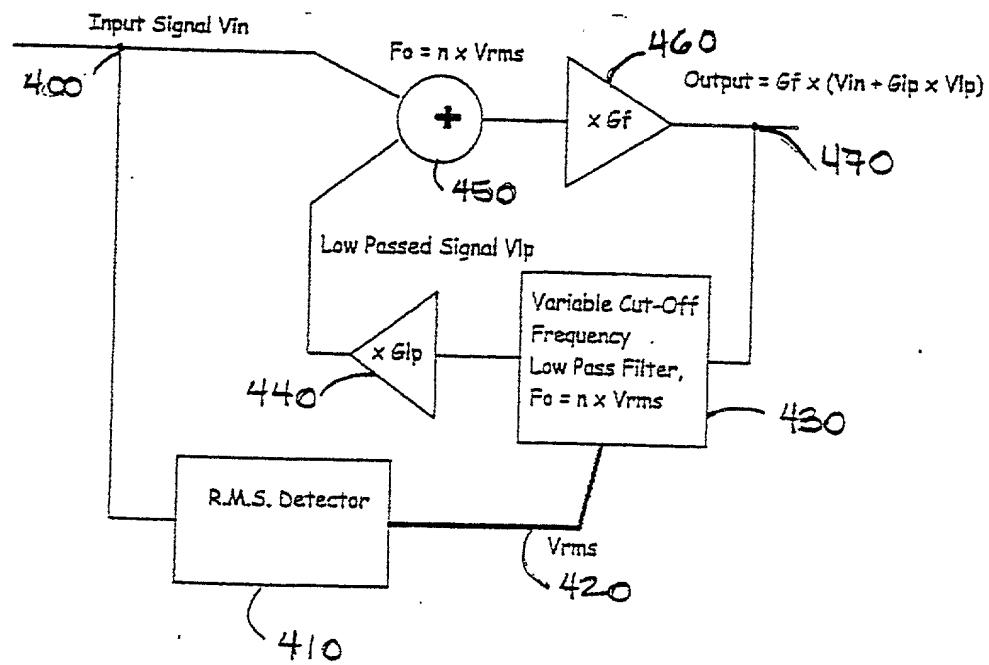


FIG. 5A

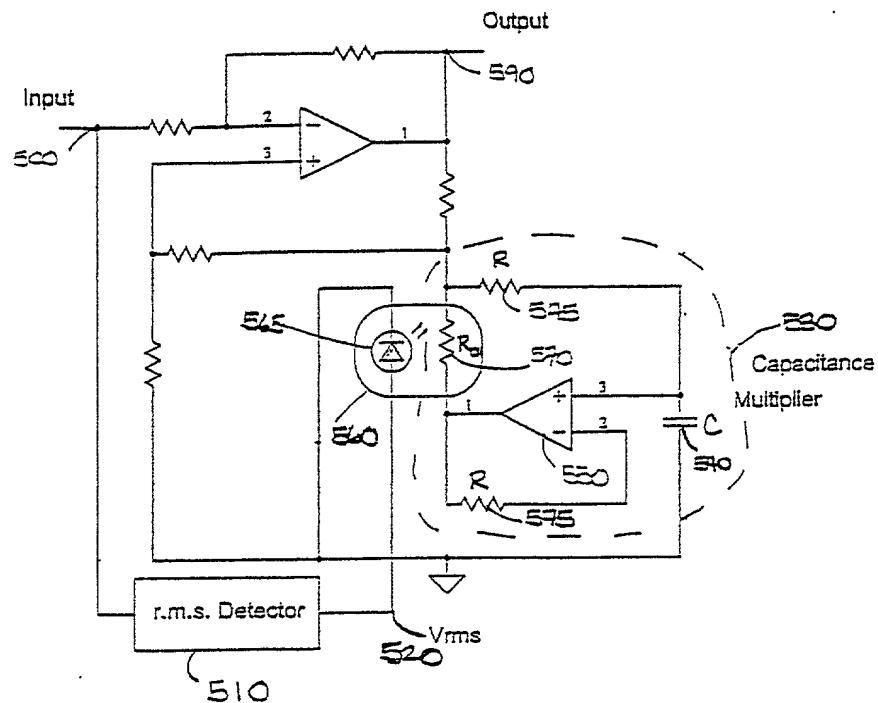
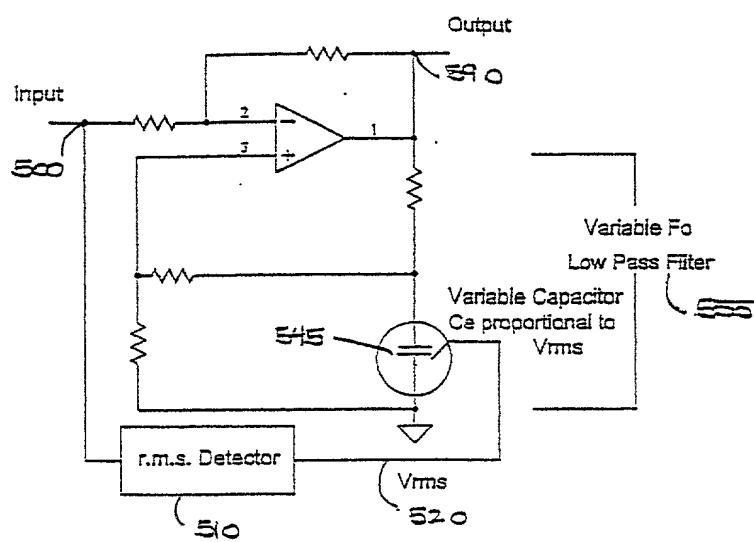


FIG. 5B



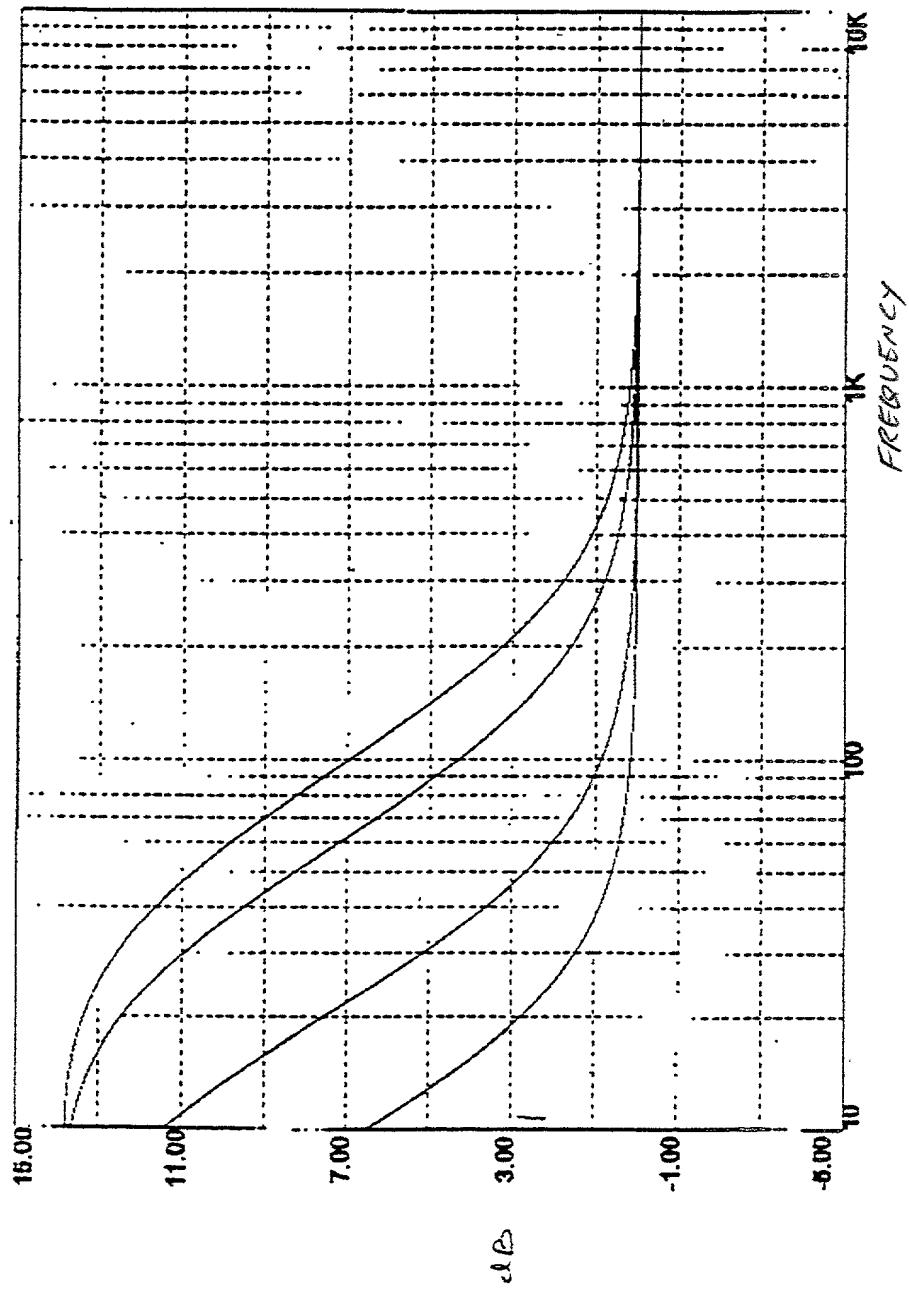


FIG. 6

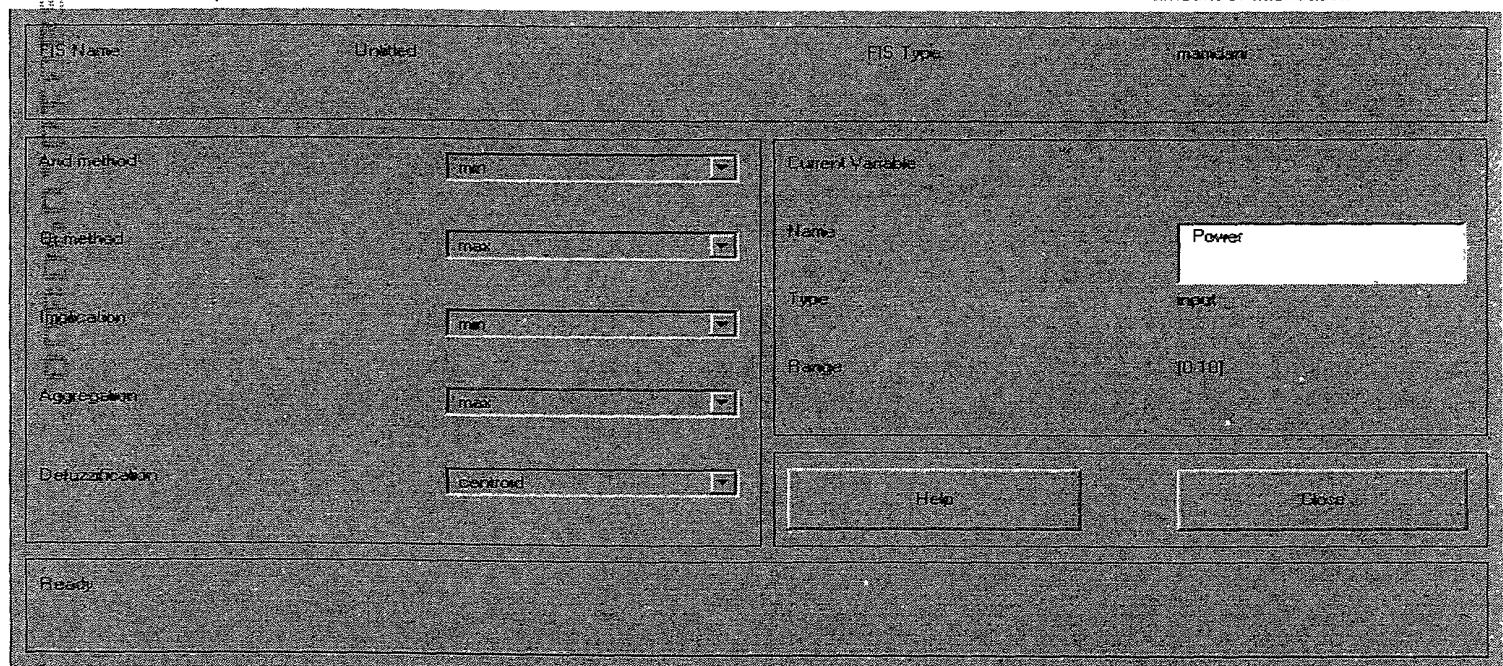
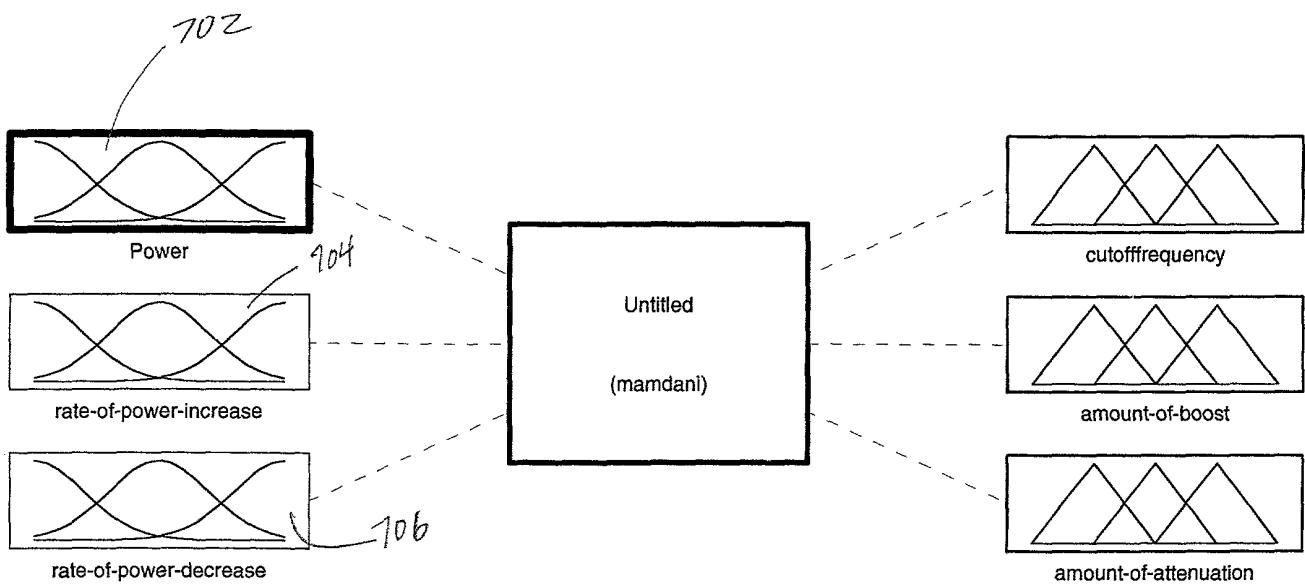
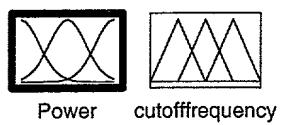
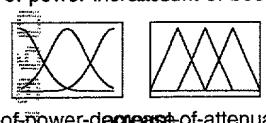


FIG. 7A

FIS Variables

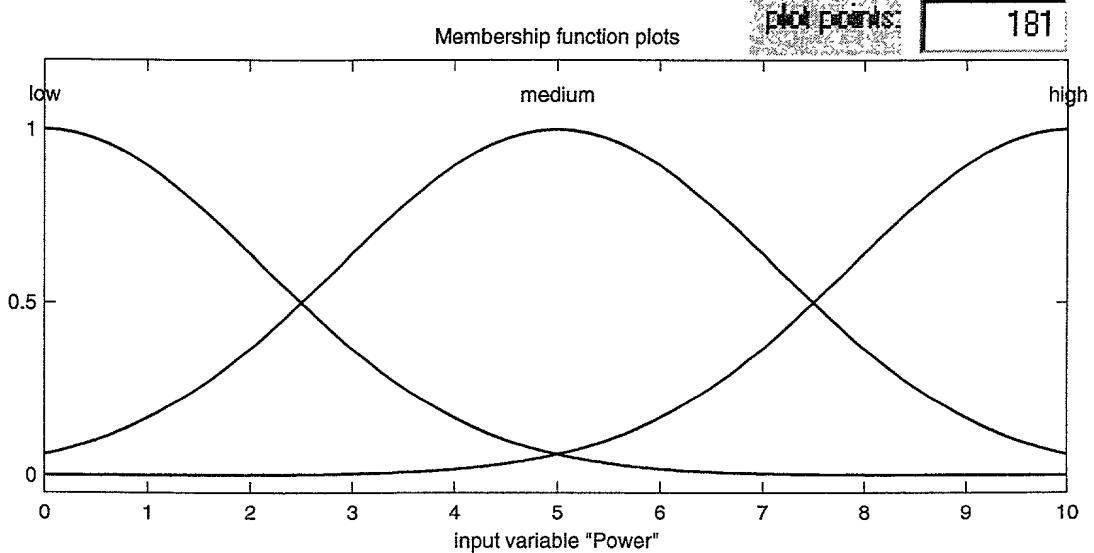


rate-of-power-increase rate-of-boost



Membership function plots

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Current Variable

Name: Power

Type: input

Range: [0 10]

Display Range: [0 10]

Ready!

Current Membership Function (click on MF to select)

Name:

Type:

Params:

Help

Close

FIG. 7B

1. If [Power is medium] and [rate of power-decrease is medium] then [cutofffrequency is medium] (amount of boost is high) (1)
2. If [Power is medium] and [rate of power-decrease is high] then [cutofffrequency is large] (amount of boost is high) (1)

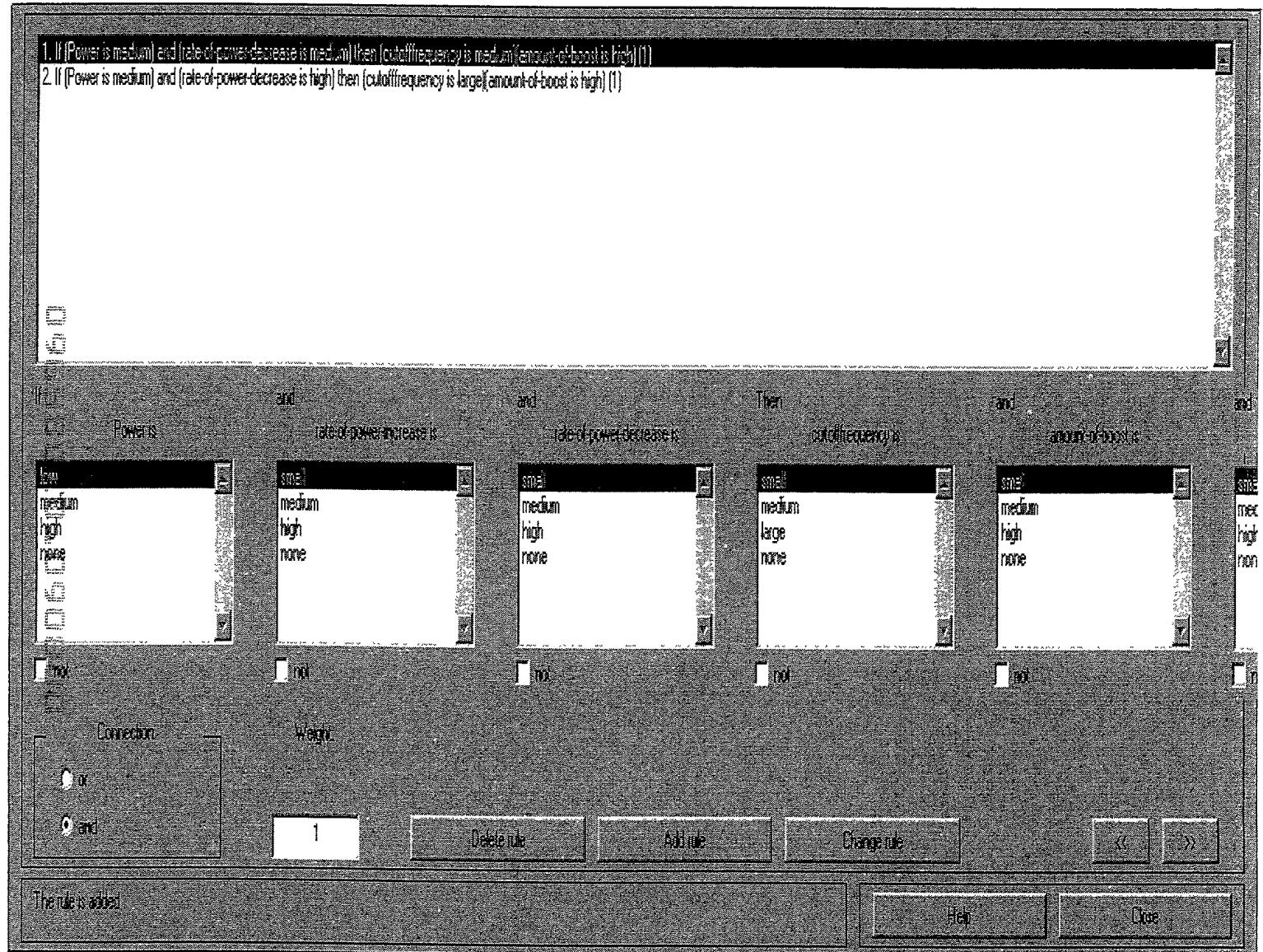


FIG. 7C

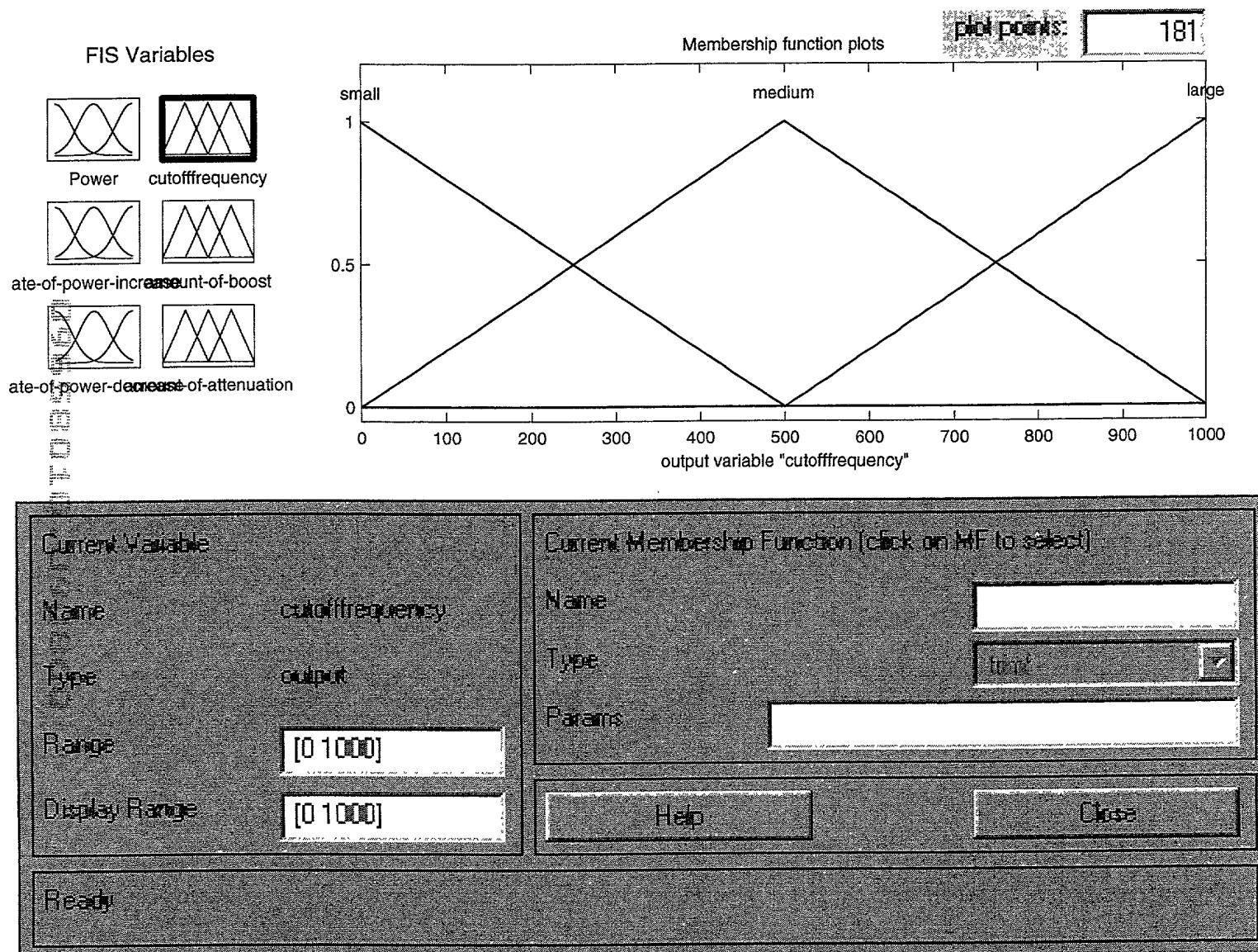


FIG. 7D

Power = 8.43 rate-of-power-increase = 2.53 rate-of-power-decrease = 4.46

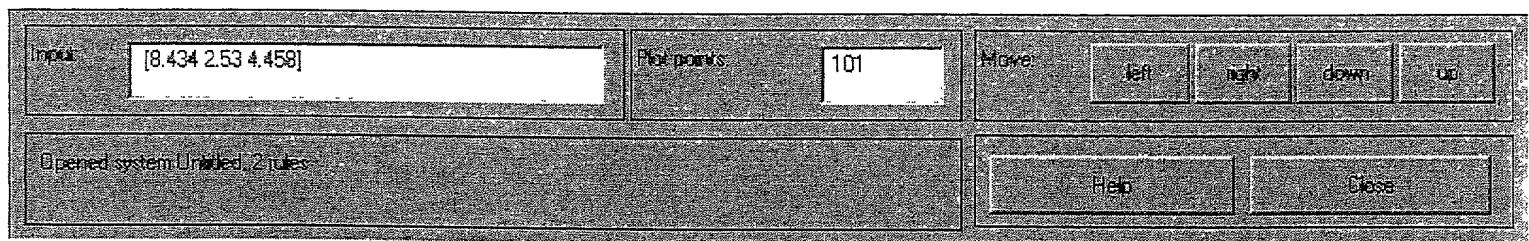
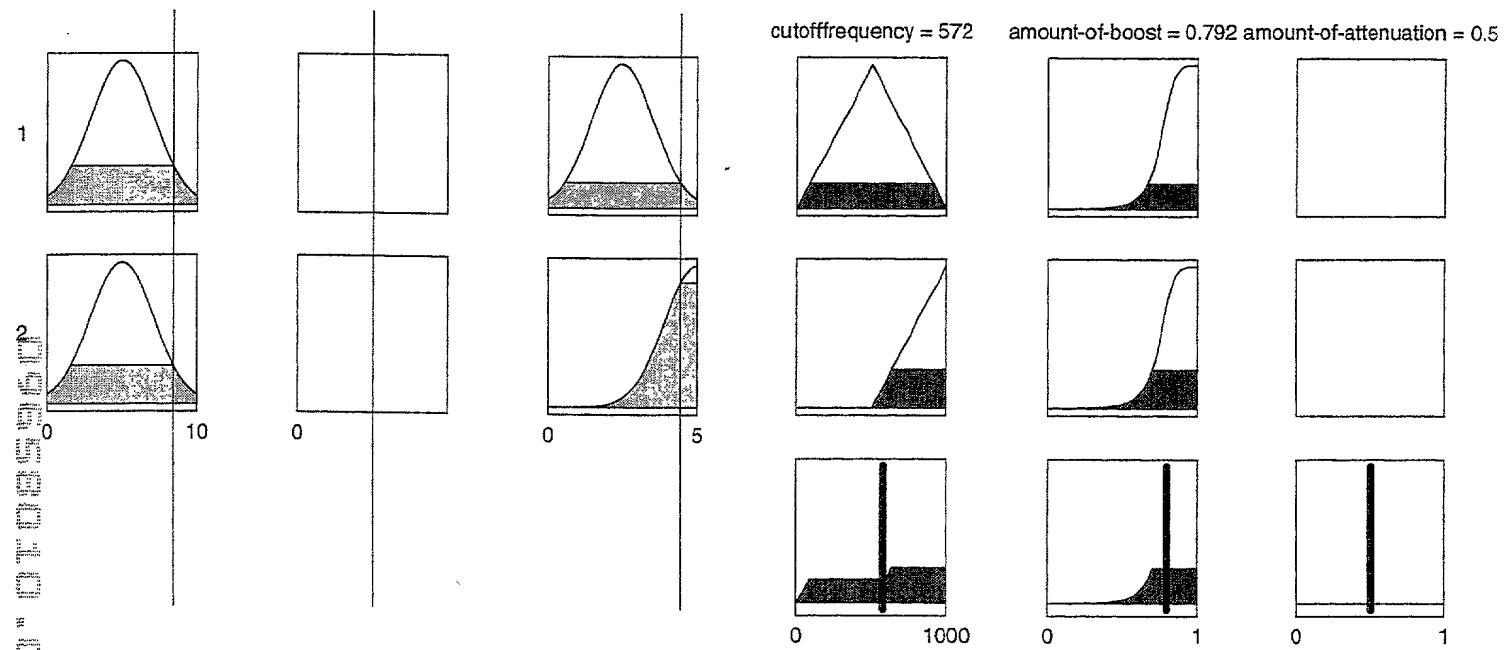


FIG. 7E

DECLARATION AND PETITION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled SYSTEM AND METHOD FOR VARYING LOW AUDIO FREQUENCIES INVERSELY WITH AUDIO SIGNAL LEVEL, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application of which priority is claimed.

Prior Foreign Application(s)

Priority Claimed

(Number)(Country)(Day, month, year filed) Yes No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.) Filing Date (Status: Patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Attn: Sung Oh
(310) 788-5000

Wherefore I pray that Letters Patent be granted to me for the invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specification and claims, declaration, and this petition.

Full name of sole or first inventor: Sunil BHARITKAR

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Citizenship: U.K.

Post Office Address: Same as above